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H2A AKC4A AK100 AK121 AK213U AK220U AK302U

(56) Documents cited
GB 2014373 A **GB 1277876 A** **EP 0170741 A1**
EP 0050814 A1

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UK CL (Edition K) **H2A AKC4 AKC4A AKC5**
INT CL[5] **H02K 1/08 19/06 19/10 19/20 19/24 37/04 37/06 37/08**

(54) Tooth shape for rotor or stator of an electrical machine

(57) A rotor or a stator of an electrical machine has a plurality of teeth (101). In Fig 4 each tooth (101) has a plurality of edges (123, 111, 109, 113, 125) divided by four points (119, 115, 117, 121) of inflexion and is symmetrical about a radial axis (107). Alternative profiles are shown in Figs 5-7.

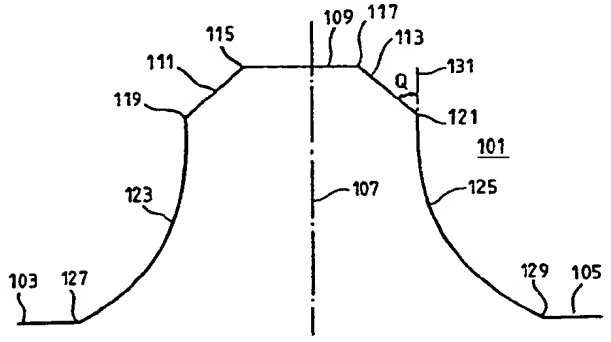

FIG.4

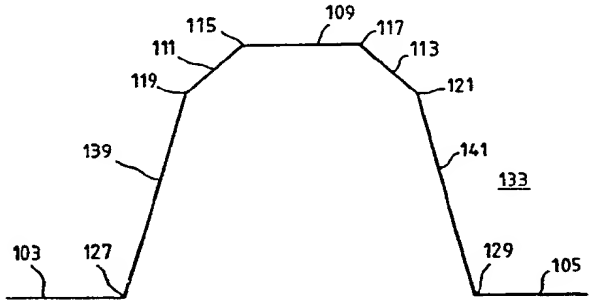

FIG.5

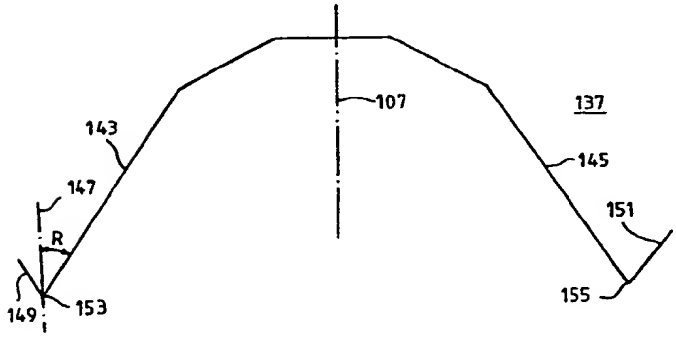

FIG.7

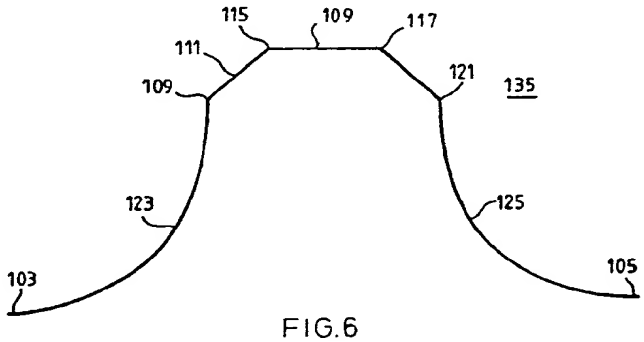

FIG.6

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1990.

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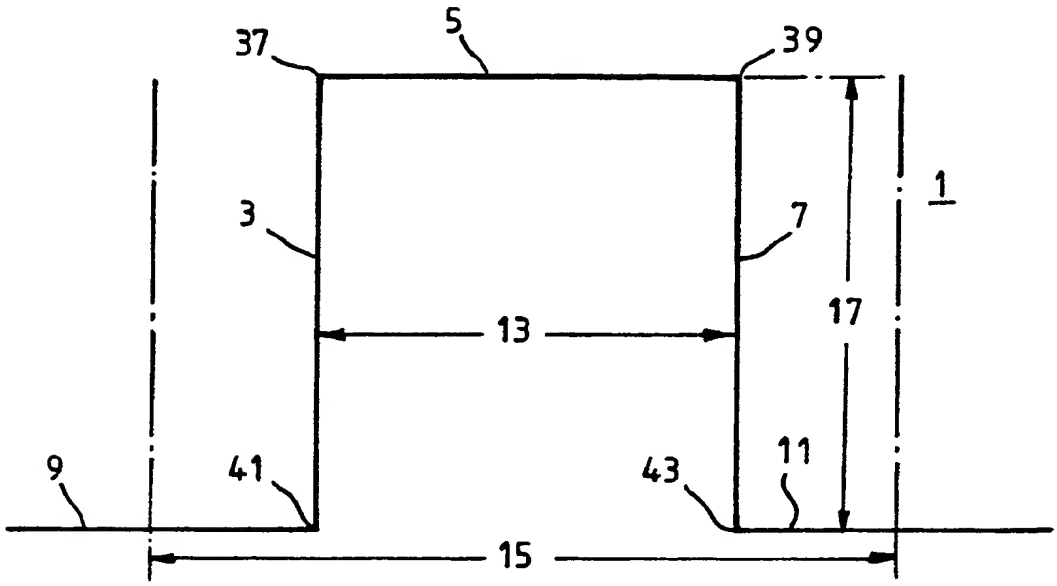

FIG.1

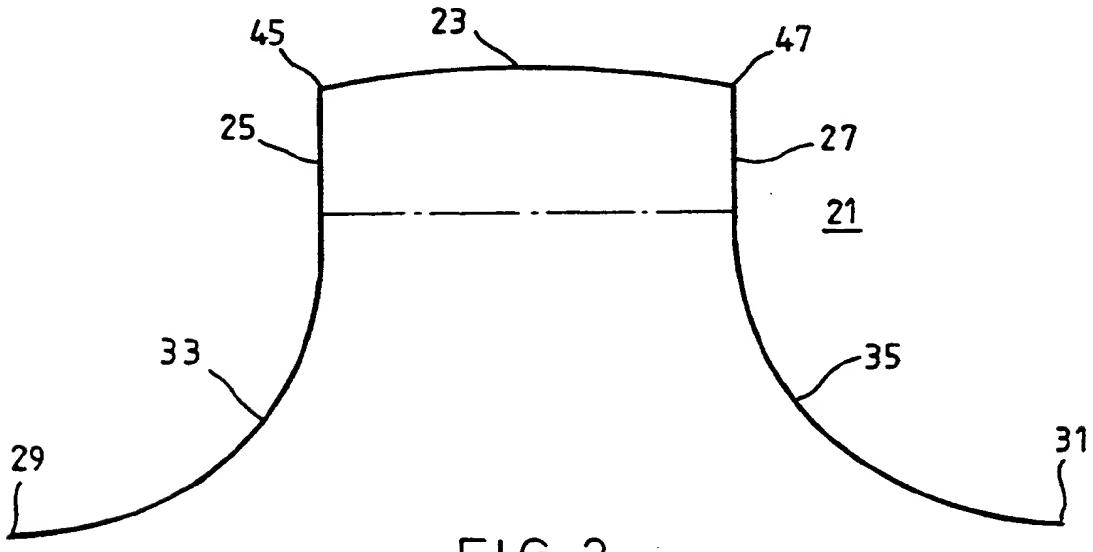

FIG.2

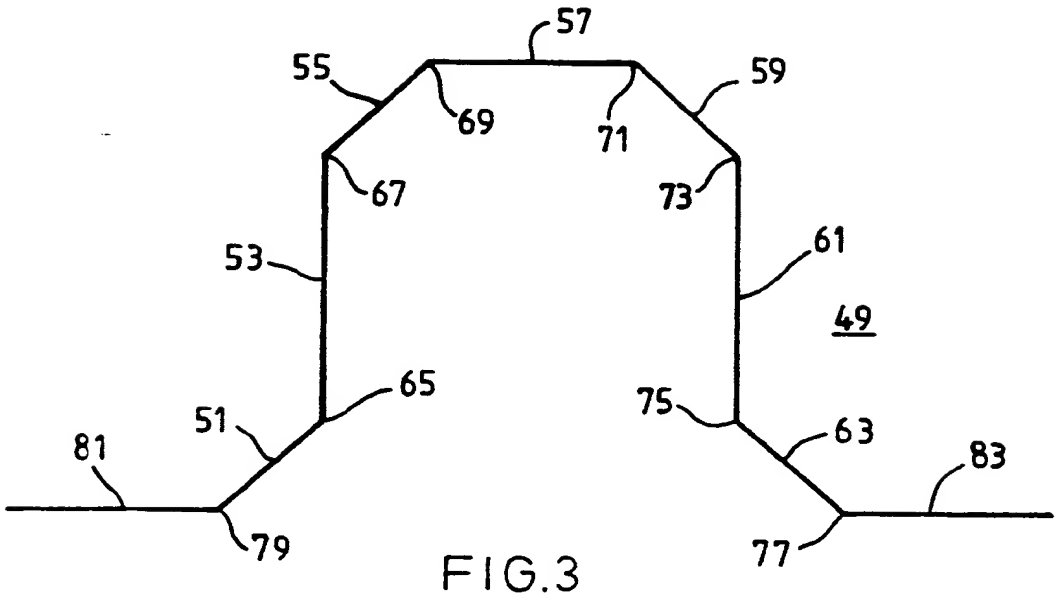

FIG.3

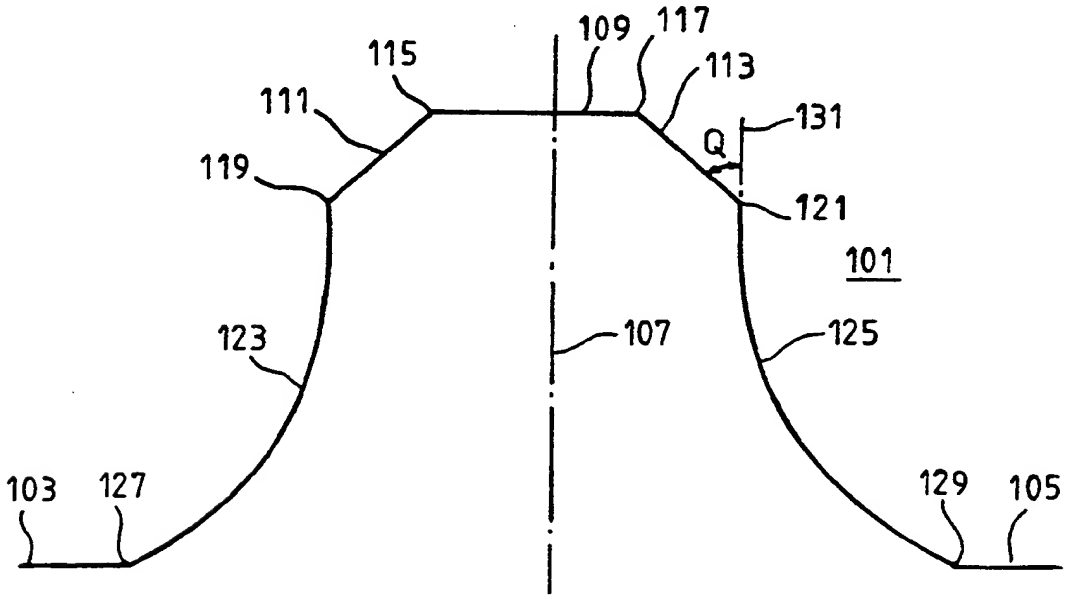

FIG.4

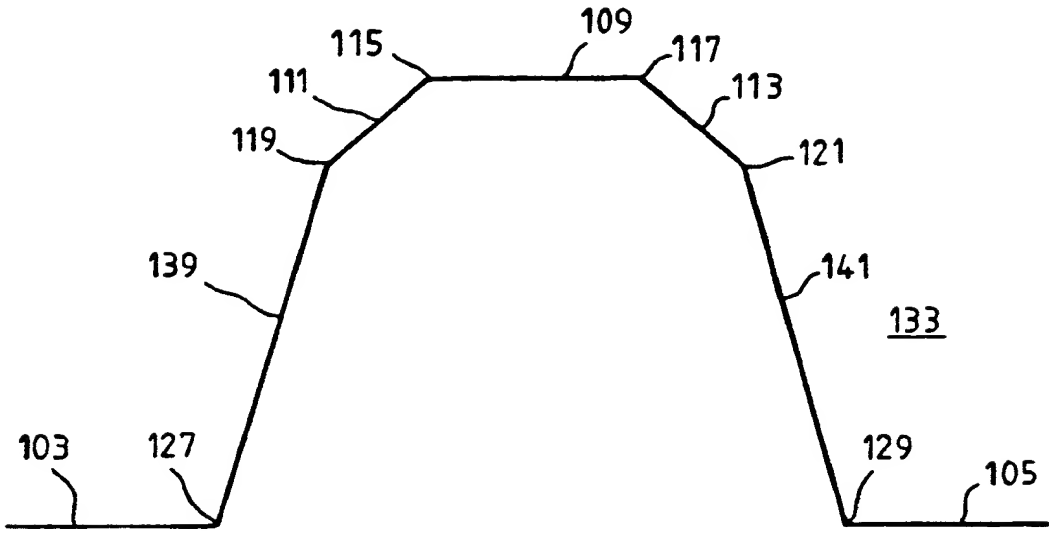

FIG.5

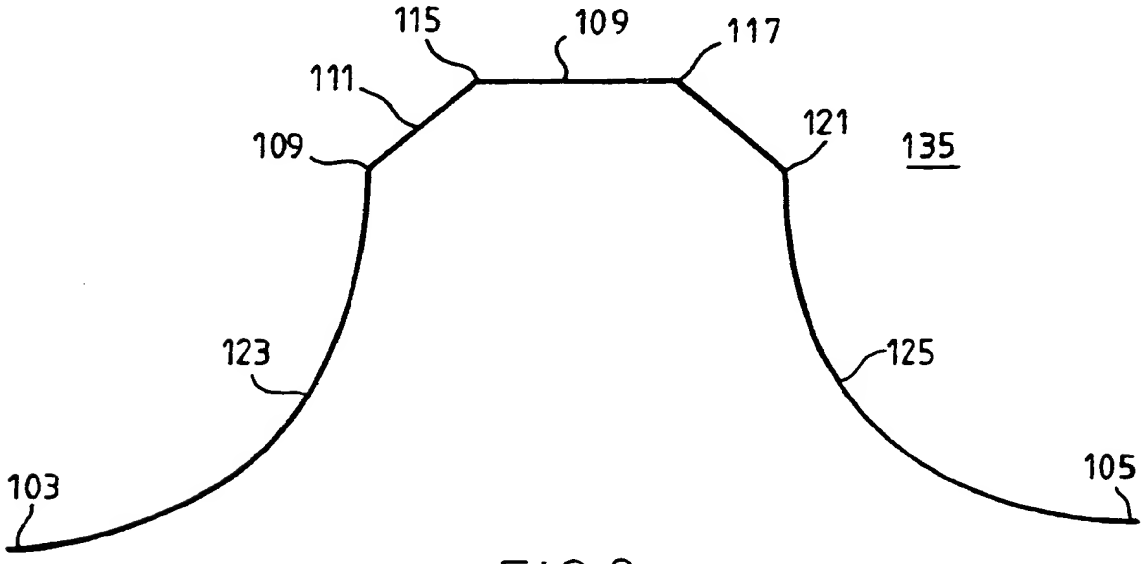

FIG.6

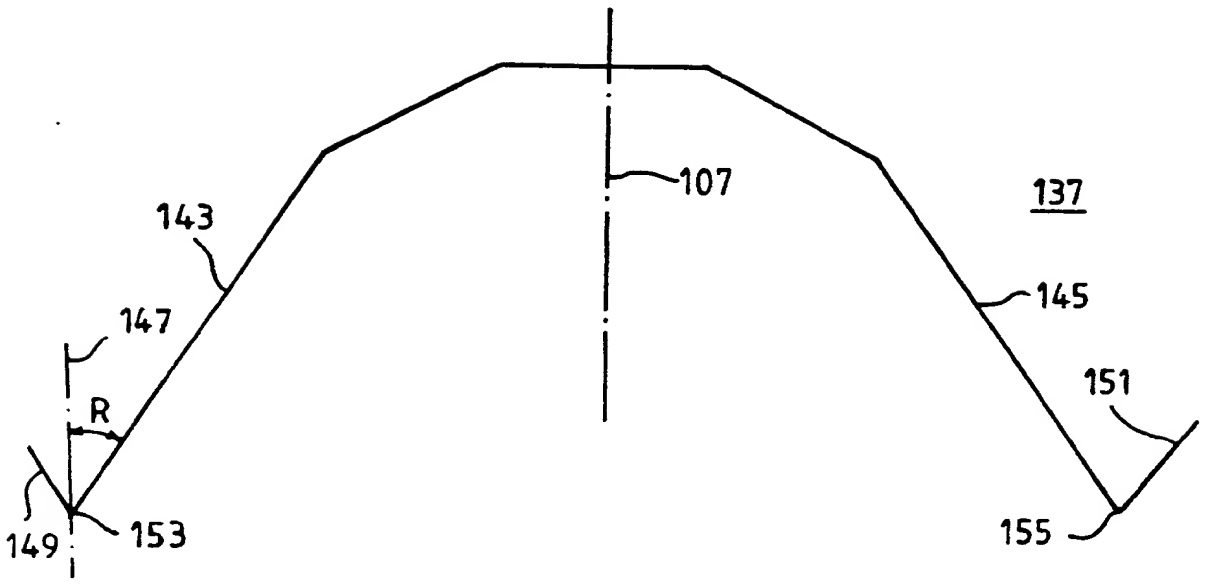

FIG.7

TOOTH SHAPE FOR ELECTRICAL MACHINE PARTS

The present invention relates to a part (eg a rotor or stator) for an electrical machine, the part being of the kind comprising a plurality of teeth spaced about its circumference.

Such parts find application in, for example, stepping motors. Stepping motors are used for imparting incremental rotational motion to a shaft in response to a pulsed signal. Typically, the toothed part may be a rotor and the pulsed signal is applied to a plurality of electromagnetic coils spaced around the inner circumference of a stator.

The shape of the teeth has a significant effect on the operation of such machines and in particular on the efficiency of conversion of electrical energy.

The simplest conventional tooth shape for such machines is rectangular, as shown in Figure 1 of the accompanying drawings. Each tooth 1 is defined by three rectangular edges 3, 5, 7 and the teeth are spaced by recessed peripheral edge lengths 9, 11 of the rotor. The ratio of tooth width 13 to pitch 15 is normally in the range 0.39 - 0.41. The ratio of tooth height 17 to pitch is known to be optimum at about 0.5. However, this does not result in a particularly high output torque. US patent specification 4 186 316 discloses a rotor having

a plurality of teeth each with sides substantially parallel to each other and to a radius midway between the sides, and also having a curved periphery having a radius of curvature less than the radius of curvature of the circle described by the outermost part of the teeth. As described, the shape of the teeth is intended to improve the precision of rotational positioning and to improve static torque whilst not reducing running torque.

Another known variant of the tooth shape shown in Figure 1 is illustrated in Figure 2. This tooth 21 comprises one circular edge 23 at the crest and two straight vertical sides 25, 27 substantially parallel to each other and to a radius midway between them. The transition region between the sides 25, 27 and the recessed peripheral edges 29, 31 consists of curved edges regions 33, 35. This configuration has no particular merit beyond convenience of manufacture.

Thus, it can be seen that the known tooth shown in Figure 1 has two points of inflexion 37, 39 and two sharp discontinuities 41, 43 defining its connection with the recessed peripheral edges 9, 11. On the other hand, the known tooth shown in Figure 2 has two points of inflexion 45, 47 and respective curved edge regions 35, 37 defining a smooth connection of the tooth with the recessed peripheral edges 29, 31.

Teeth formed according to the disclosure of US patent specification 4 186 316 also have two points of inflexion separating the respective edges. The junction of each tooth with the recessed edges of the rotor are in this case marked by sharp discontinuities. The middle edge of each tooth (at the remote periphery) is curved.

Another known tooth shape is shown in Figure 3. This is the subject of patent application number CN 86206257 U of the People's Republic of China. It is particularly intended for use in variable reluctance stepper motors. The tooth 49 as shown comprises seven straight edges 51, 53, 55, 57, 59, 61, 63 separated by six points of inflexion 65, 67, 69, 71, 73, 75. Two sharp discontinuities 77, 79 define the connection between the lower edges 51, 63 and respective recessed peripheral edges 81, 83 of a rotor.

Experimental results have demonstrated that the tooth shape as shown in Figure 3 has the capability of increasing torque by 14 - 17% and greatly improving performance. However the seven edges plus recessed peripheral edges present more difficulties in making dies for punching laminations, compared to the tooth shapes in Figure 1 and Figure 2 which have only three (plus recessed peripheral edges). This is because the number of edges increases the number of apexes at the

points of inflexion. These apexes are weak points. They also greatly reduce the life of dies used to form them. When the laminations are punched, this weakness can cause breakage and inaccuracy in final dimensions.

It has now been discovered that the drawbacks associated with the known teeth structures referred to above can be overcome by providing according to the present invention, a part for an electrical machine, the part comprising a plurality of teeth, at least one of which comprises a plurality of edges divided by four points of inflexion.

The part according to the present invention may for example be a rotor or a stator.

Preferably, the at least one tooth is symmetric about a radial axis, ie a notional radial line drawn from the centre of the rotor. In that case, one edge (the middle edge) will be substantially perpendicular to that axis.

Any or all of the edges may be straight or curved or of any other shape but generally, it is preferred that the middle edge is curved and the edge either side of the middle edge are substantially straight. Most preferably, the middle edge has the shape of an arc of a circle centred at the geometrical centre of the part. The transitions between the at least one tooth and

respective recessed edges may be smooth or defined by a discontinuity (angle).

Most preferably, all the teeth of rotors according to the present invention are substantially the same as each other and therefore conform to the profile of the said at least one tooth.

Parts according to the present invention may be used in a wide variety of electric machines, for example those which rely fully or partially on reluctance torque, variable reluctance stepper motors, hybrid stepper motors, synchronous reluctance machines or switched reluctance drives.

The present invention will now be explained in more detail by the following description of a preferred embodiment and with reference to the accompanying drawings in which: -

Figure 1 shows a known tooth profile;

Figure 2 shows a second known tooth profile;

Figure 3 shows a third known tooth profile;

Figure 4 shows a tooth profile of a rotor according to a first embodiment of the present invention;

Figure 5 shows a tooth profile of a rotor according to a second embodiment of the present invention;

Figure 6 shows a tooth profile of a rotor according

to a third embodiment of the present invention; and

Figure 7 shows a tooth profile of a rotor according to a fourth embodiment of the present invention.

The specific embodiments of the invention described below relate to rotors. However, it will be appreciated that the tooth shapes described may equally be applied to, for example, a stator.

In a first embodiment of the present invention, a circular rotor comprises a plurality of substantially equally spaced teeth 101 as shown in Figure 4. The teeth are located on the periphery of the rotor, separated by recessed edges 103, 105 of the rotor. The tooth is substantially symmetric about a notional radial axis 107. A middle edge 109 in the shape of an arc of a circle and located at the crest of the tooth is joined on either side by respective straight side edges 111, 113. The boundaries between the latter two edges and the middle edge are defined by respective first and second points of inflexion 115, 117.

At respective third and fourth points of inflexion 119, 121, remote from points 115, 117, the straight side edges meet respective concave curved edges 123, 125. At their remote ends 127, 129 remote from the third and fourth points of inflexion, the concave curved edges meet the recessed edges 103, 105 of the rotor.

In the region adjacent the third and fourth points of inflexion, the concave curved edges are approximately straight and approximately parallel to the axis 107. The straight side edges are at an angle Q relative to a notional extension 131 of the concave curved edges, or to a line parallel to the axis. The angle Q is in the range from 5° to 65°. The overall relative dimensions could also vary. Thus, for example, the height of the middle edge 109 above the recessed rotor edges 103, 105 could be higher or lower. The concave curved side edges 123, 125 could for example have a circular or quadratic function profile.

Using the tooth shape shown in Figure 4 results in a torque increase of from approximately 15% to approximately 30% relative to the shape shown in Figure 1. At the same time, it overcomes the manufacturing difficulties encountered with the shape shown in Figure 3.

The precise configuration of the tooth will vary according to the intended application. In the light of this disclosure the optimum parameters for a particular machine will now be calculable by persons skilled in the art using a non-linear field calculation implemented as a suitable computer program or by any other appropriate method.

Figures 5 through 7 illustrate tooth profiles of rotors according to other embodiments of the present invention. These rotors are indicated by reference numerals 133, 135, 137 respectively. However, parts which are the same as for the tooth shown in Figure 4 are designated by the same reference numerals and different numerals are only used for those parts that differ with respect to the embodiment shown in the latter drawing.

Thus, as shown in Figure 5, instead of the concave curved edges 123, 125, respective straight side edges 139, 141 extend from the third and fourth points of inflexion 119, 121 to the discontinuities 127, 129 where they join the recessed edges 103, 105 of the rotor.

In the embodiment shown in Figure 6, the only difference with respect to that shown in Figure 4 is that the discontinuities 127, 129 are dispensed with and there is a smooth curved transition between the concave curved side edges 123, 125 and the recessed rotor edges 103, 105.

With the embodiment of Figure 7, the concave curved side edges 123, 125 are replaced by substantially straight side edges 143, 145. However, there are still two differences with respect to the embodiment shown in Figure 5.

First, the angle R between the straight side edges 143, 145 and notional lines 147 parallel to the axis of symmetry 107 is greater than the equivalent angle for the embodiment of Figure 5. Second, the recessed rotor edges 103, 105 are dispensed with and the tooth 137 abuts adjacent teeth 149, 151 at respective notches 153, 155.

In the light of this disclosure, modifications of the described embodiments as well as other embodiments, all within the scope of the invention as hereinbefore defined will now be apparent to persons skilled in the art.

CLAIMS

1. A part for an electrical machine, the part comprising a plurality of teeth, at least one of which comprises a plurality of edges divided by four points of inflexion.

2. A part for an electrical machine according to claim 1, wherein the at least one tooth is symmetrical about a radial axis.

3. A part for an electrical machine according to claim 1 or claim 2, wherein a middle edge is curved and the edge either side of the middle edge is substantially straight.

4. A part for an electrical machine according to claim 3, wherein the middle edge has the shape of an arc of a circle centred at the geometrical centre of the part.

5. A part for an electrical machine according to any of claims 1 to 4, wherein the transitions between the at least one tooth and respective recessed edges may be smooth or defined by a discontinuity (angle).

6. A part for an electrical machine according to any of claims 1 to 5 which is a rotor or a stator.

7. A part for an electrical machine according to claim 6, wherein all the teeth of the rotors and stators are substantially the same as each other.

8. A part for an electrical machine, the part comprising a plurality of teeth, substantially as hereinbefore described with reference to Figures 4 to 7 of the accompanying drawings.

Amendments to the claims have been filed as follows

1. A part for an electrical machine, the part comprising a plurality of teeth, at least one of which comprises a plurality of edges divided by four points of inflection, said at least one tooth being divided by two of the points of inflection into an outer portion and an inner portion, the outer portion being generally trapezoidal and the inner portion being generally trapezoidal.

2. A part for an electrical machine according to claim 1, wherein the inner portion of said at least one tooth has recessed peripheral edges.

3. A part for an electrical machine according to claim 1 or claim 2, wherein the said at least one tooth is symmetrical about a radial axis.

4. A part for an electrical machine according to any of claims 1 to 3, wherein a middle edge of said at least one tooth is curved and the edge either side of the middle edge is substantially straight.

5. A part for an electrical machine according to claim

4, wherein the middle edge has the shape of an arc of a circle centred at the geometrical centre of the part.

6. A part for an electrical machine according to any of claims 1 to 5, which is a stator or a rotor.

7. A part for an electrical machine according to claim 5, wherein all the teeth of the rotor or stator are substantially the same as each other.

8. A part for an electrical machine, the part comprising a plurality of teeth, substantially as hereinbefore described with reference to Figures 4 to 7 of the accompanying drawings.

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Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

Application number
9122529.2

Relevant Technical fields

(i) UK Cl (Edition K) H2A (AKC4A, AKC4, AKC5)

(ii) Int CL (Edition 5) H02K 01/08, 37/04, 37/06, 37/08, 19/06, 19/10, 19/20, 19/24

Search Examiner
J COCKITT

Databases (see over)

(i) UK Patent Office

(ii)

Date of Search
29 APRIL 1992

Documents considered relevant following a search in respect of claims 1-8

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
X	GB 2014373A (HITACHI) See pole 11	Claim 1 at least
X	GB 1277876A (LUCAS) See pole structure 15,16	Claim 1 at least
X	EP 0170741A1 (JAPAN) See Figure 4	Claim 1 at least
X	EP 0050814A1 (FUJITSU) See pole structure 42 Figure 3	Claim 1 at least

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Category	Identity of document and relevant passages	Relevant to claim(s.

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